SPECIFIED GAS EMITTERS REGULATION

QUANTIFICATION PROTOCOL FOR AEROBIC LANDFILL BIOREACTOR PROJECTS

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Version 1

Alberta ENVIRONMENT

ALBERTANS & CLIMATE CHANGE

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1.0 Project and Methodology Scope and Description

This quantification protocol is written for the aerobic landfill bioreactor project developer. This protocol is written assuming the reader has some familiarity with or general understanding of, waste management practices including aerobic composting and the operation of a landfill.

The opportunity for generating carbon offsets with this protocol arises from directly avoiding methane emissions from materials anaerobically decomposing in landfills. Specifically, this protocol covers landfills or landfill cell(s) which are at capacity / will not be accepting more waste materials, and are covered. Rather than the content of these landfills or landfill cell(s) decomposing anaerobically and producing methane, wells are drilled for the purposes of aerating the waste and recirculating leachate. Conditions are maintained to support aerobic decomposition of the waste. The resulting carbon dioxide emissions are considered as biogenic.

1.1 Protocol Scope and Description

The project condition is that of an aerobic landfill bioreactor. This protocol can be applied to existing landfills or landfill cells that are retro-fitted to incorporate an aerobic landfill bioreactor, as well as to landfills or landfill cells that were originally designed and constructed to employ the use of aerobic landfill bioreactor technology.

Wells are drilled at various depths throughout the landfill or landfill cell(s). Some of these wells are used for pumping air into the waste material and recirculating leachate, while the rest are used as vents for the escaping gases. This provides the conditions to support aerobic decomposition and thus the production of carbon dioxide as the main product of decomposition. This carbon dioxide then follows a preferential escape pathway up and out of the venting wells.

FIGURE 1.1 offers a process flow diagram for a typical project.

Protocol Approach:

Typically, in the baseline condition, landfill gas (LFG) is passively emitted due to the anaerobic decomposition of the organic components within a landfill. The aerobic landfill bioreactor may be installed at sites where there was previously a landfill collection and destruction system. This would indicate that the previously installed system was not meeting the operational objectives for the site and the technology addresses the remaining methane potential at the site. Therefore, the baseline condition would revert to the passive emission of landfill gas generated under anaerobic conditions unless otherwise mandated by law.

FIGURE 1.2 offers a process flow diagram for a typical baseline configuration.

FIGURE 1.1: Process Flow Diagram for Project Condition

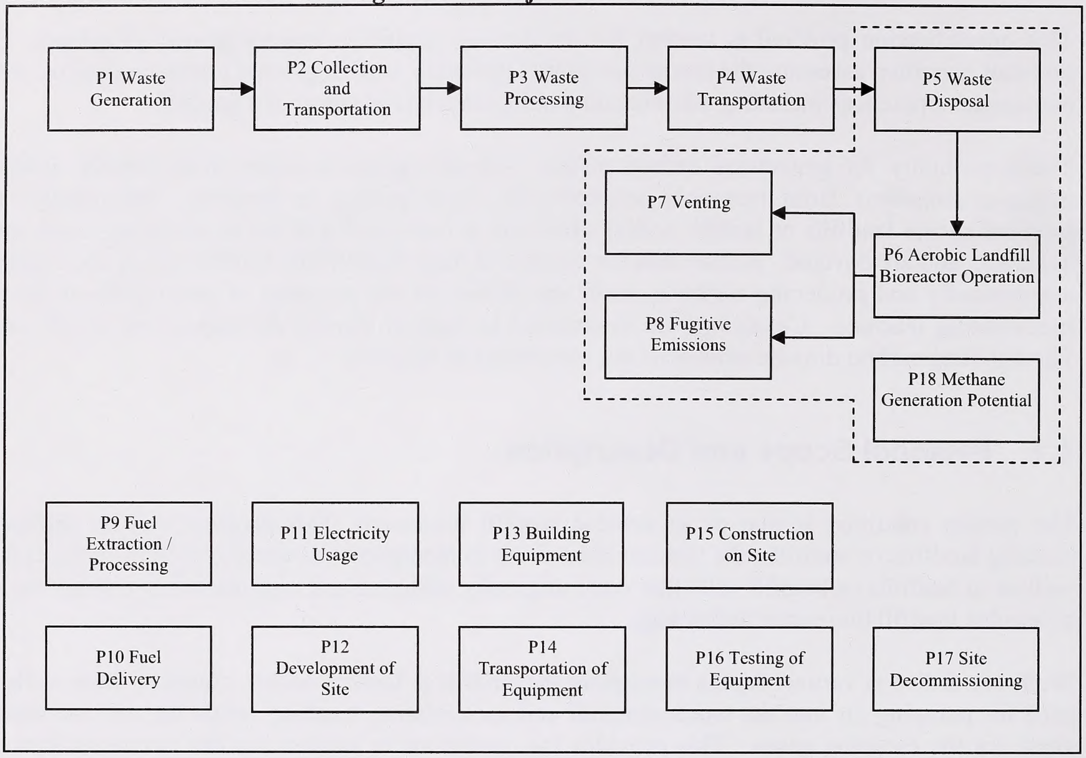
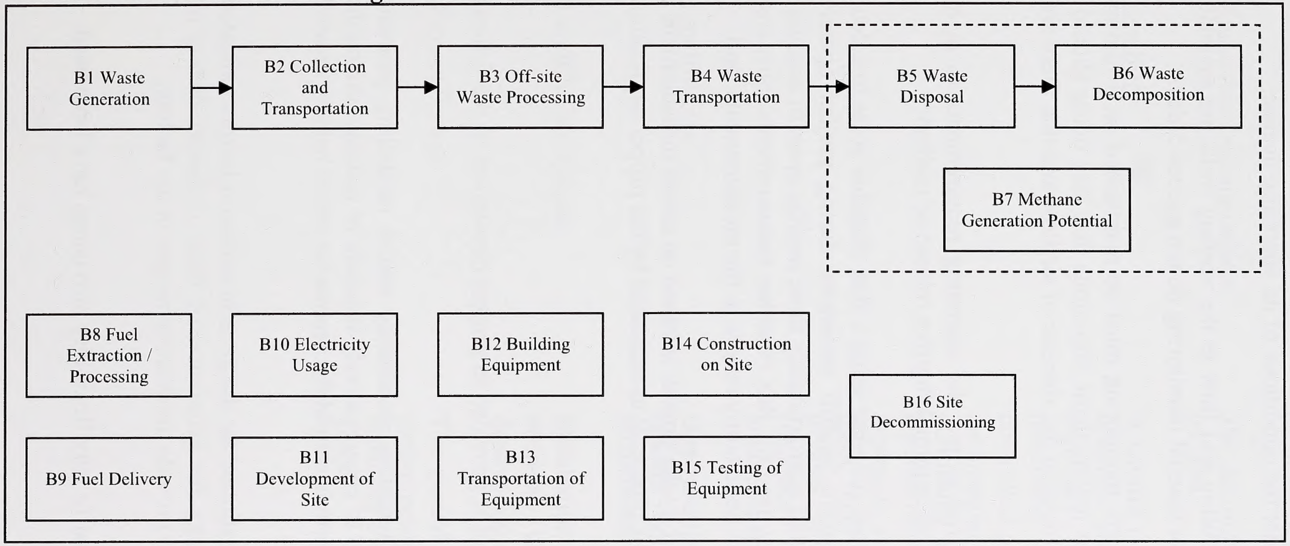


FIGURE 1.2: Process Flow Diagram for Baseline Condition



Protocol Applicability:

To meet the requirements under this protocol, the project developer must supply sufficient evidence to demonstrate that:

1. The landfill facility is being operated under the conditions of its operating license;

2. The monitoring of the methane concentration and flow in the venting wells are maintained consistently and that gaps in automated or manual monitoring do not exceed 5 days;

3. During shut-downs of the aeration system, monitoring must be maintained on a minimum frequency of every 5 days, to account for any methane emissions that may occur should the bioreactor revert back to anaerobic conditions in the absence of air flow and that there are no material fugitive emissions of methane;

4. The landfill or landfill cell(s) are covered as per the operating requirements to manage passive landfill gas migration, and therefore minimal fugitive release of methane;

5. Fugitive emissions are measured four times per year using a flux chamber so as to calculate the flow rate and concentration of passive landfill emissions during project operation. Quarterly measurements must be conducted approximately three months apart to account for seasonal variations, and the methodology used for flux chamber measurements must ensure accuracy and be robust enough to provide uncertainty ranges in the measurements; and

6. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol.

Protocol Flexibility:

Flexibility in applying the quantification protocol is provided to project developers in the following ways:

1. During extended shut-down periods, alternative monitoring and/or modelling procedures may be implemented that must be shown to conservatively measure or estimate the methane emissions that may result during these periods should the bioreactor revert back to anaerobic conditions in the absence of air flow.

2. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must ensure accuracy; and be robust enough to provide uncertainty ranges in the factors;

If applicable, the proponent must indicate and justify why flexibility provisions have been used.

1.2 Glossary of New Terms

Aerobic Landfill Bioreactor:	A landfill cell that is specifically engineered to enhance the aerobic decomposition of wastes through careful manipulation of site conditions
Anaerobic Decomposition:	The decomposition of organic matter in the absence of oxygen.
Landfill:	A landfill is a site at which materials are stored where they can undergo anaerobic decomposition. This may include the materials being buried, piled, mixed with other waste materials, or otherwise. Landfills, classified as either controlled or uncontrolled, are included in this definition. The designation of controlled or uncontrolled refers to the level of permitting and technical controls in place at the disposal site. Uncontrolled landfills may exist where although there is no expressly stated goal to leave the materials in place, there is a track record of material residing in that place for extended periods (greater than 10 years) and there are no plans or regulatory requirements for the material to be transferred to another disposal site.
Landfill Gas:	Gas resulting from the decomposition of wastes placed in a landfill typically comprised primarily of methane, carbon dioxide and other trace compounds.
Landfill Gas System:	Installation of infrastructure that in operating causes a decrease in GHG emissions through the collection and destruction of the methane component of LFG.
Project Period:	The period of time in between methane generation potential measurements - also known as the reporting period. The crediting cycle is eight years with possible renewable for five years.

2.0 Quantification Development and Justification

The following sections outline the quantification development and justification.

2.1 Identification of Sources and Sinks (SS's) for the Project

SS's were identified for the project by reviewing the relevant process flow diagrams and consulting with project developers. This process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided in **FIGURE 1.1**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1.**

FIGURE 2.1: Project Element Life Cycle Chart

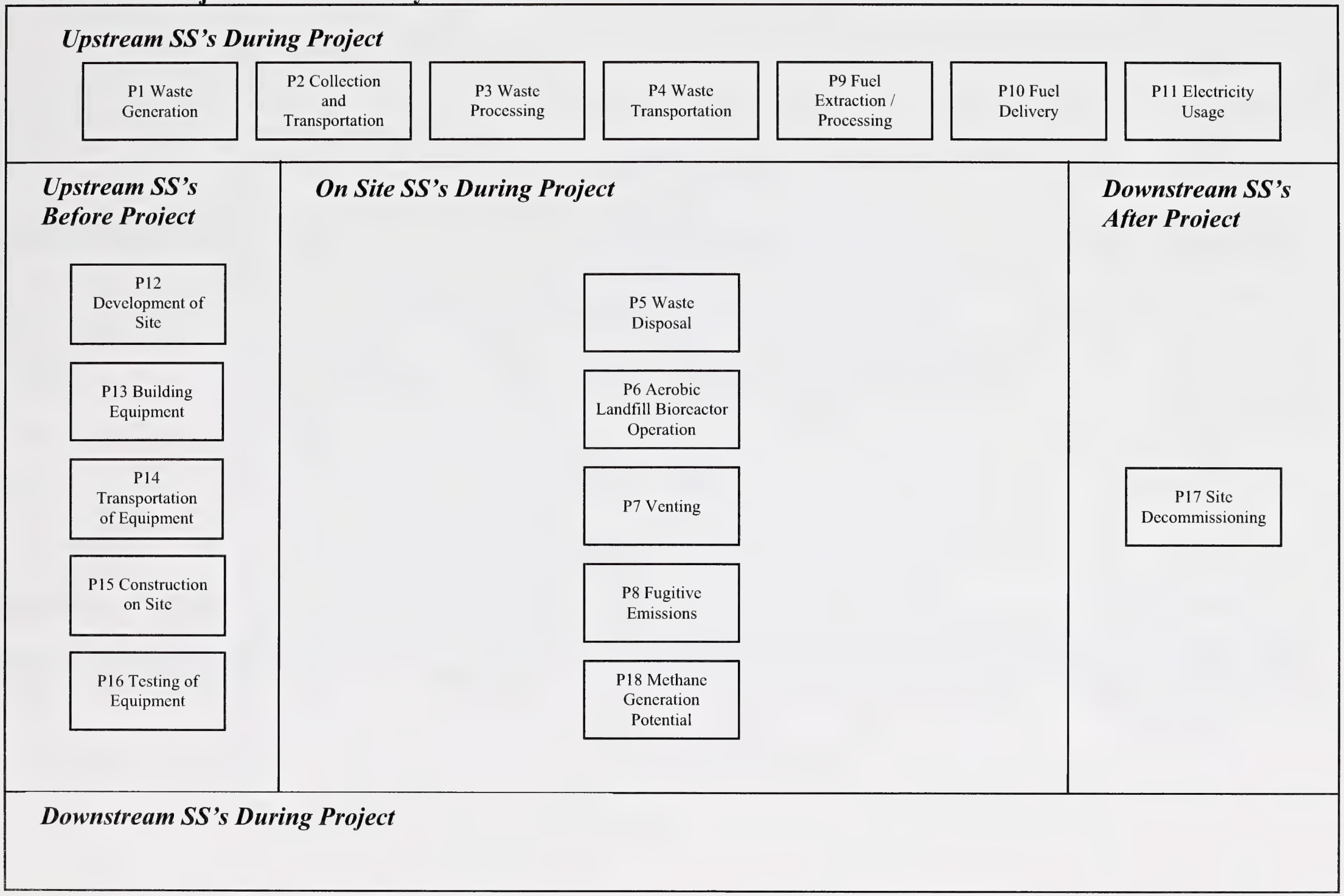


TABLE 2.1: Project SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P1 Waste Generation	Streams of solid waste are produced in a number ways, depending on the source of these residues. Quantities for each of the energy inputs related to the generation of the waste streams would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P2 Collection and Transportation	Solid waste may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P3 Waste Processing	Solid waste may be processed using a series of mechanical processes, heavy equipment and conveyors. This equipment would be fuelled by diesel, gasoline, or natural gas resulting in GHG emissions, or electricity. Quantities and types for each of the energy inputs would be tracked.	Related
P4 Waste Transportation	Solid waste may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P5 Waste Disposal	Waste may be handled at a disposal site by transferring the waste from the transportation container, spreading, burying, processing, otherwise dealing with the waste using a combination of loaders, conveyors and other mechanized devices. This equipment would be fuelled by diesel, gasoline or natural gas, resulting in GHG emissions. Other fuels may also be used in some rare cases. Quantities and types for each of the energy inputs may need to be tracked.	Related
P9 Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related

P10 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
P11 Electricity Usage	Electricity may be required for operating the facility. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
Onsite SS's during Project Operation		
P6 Aerobic Landfill Bioreactor Operation	Landfill bioreactors require compressors and other equipment for the gathering and distribution of the water and air at the project facility. This equipment may be fuelled by diesel, gasoline or natural gas, resulting in GHG emissions. Other fuels, such as landfill gas, may also be used in some rare cases. Quantities and types for each of the energy inputs may need to be tracked.	Controlled
P7 Venting	Landfill bioreactors produce greenhouse gases which are vented to the atmosphere. The gases generated are preferentially vented through venting wells as the applicable cells are capped. Quantities and concentrations of methane must be tracked. The carbon dioxide vented is biogenic and therefore needn't be measured.	Controlled
P8 Fugitive Emissions	The preferential escape route for the gases generated is through the venting wells. However, some of these gases may passively escape through the landfill cover. The flow rate and concentration of these fugitive emissions would be tracked.	Controlled
P18 Methane Generation Potential	Waste decomposes to produce methane. The amount of waste that has not yet decomposed has the potential to produce methane at a future period of time. This methane generation potential would be tracked.	Controlled
Downstream SS's during Project Operation		
	None	
Other		
P12 Development of Site	The site may need to be developed. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer, etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as equipment storage areas, offices, leachate storage containers, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related

P13 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P14 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
P15 Construction on Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity.	Related
P16 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
P17 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

2.2 Identification of Baseline

The baseline condition represents the emissions of greenhouse gases (mainly methane) from the organic component of the waste decomposing in a landfill or landfill cell(s) that would have resulted had the aerobic landfill bioreactor not been implemented. The baseline is therefore dependent upon the methane generation potential (Lo) of the landfill or landfill cell(s), the value of which is determined through direct landfill sampling and analysis using the biochemical methane potential assay approach. Had the landfill employed landfill gas capturing technology prior to the project, this system can be assumed to no longer be either technically or economically feasible given that it is being replaced with this technology, and thus landfill gas collection is not appropriate as a baseline.

The approach to quantifying the baseline is direct sampling of the landfill providing the highest level of certainty available.

The baseline condition is defined, including the relevant SS's and processes, as shown in **FIGURE 1.2**. More detail on each of these SS's is provided in Section 2.3, below.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in **TABLE 2.2.**

FIGURE 2.2: Baseline Element Life Cycle Chart

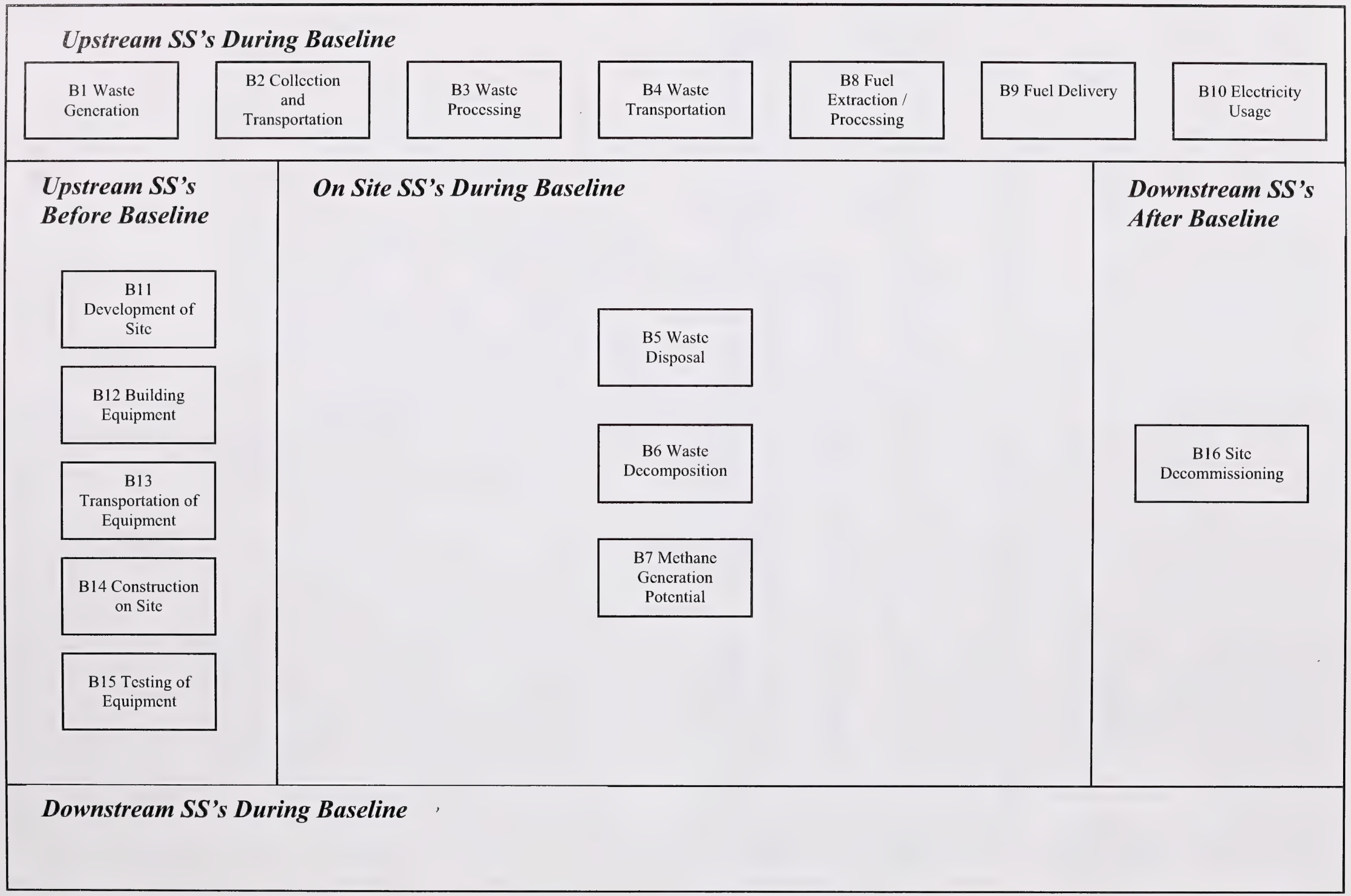


TABLE 2.2: Baseline SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Baseline Operation		
B1 Waste Generation	Waste is produced in a number ways, depending on the source of these materials. Quantities for each of the energy inputs related to the waste would be contemplated to evaluate functional equivalence with the project condition.	Related
B2 Collection and Transportation	Materials may be transported to the baseline site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B3 Waste Processing	Waste may be processed using a series of mechanical processes, heavy equipment and conveyors. This equipment would be fuelled by diesel, gasoline, or natural gas resulting in GHG emissions, or electricity. Quantities and types for each of the energy inputs would be tracked.	Related
B4 Waste Transportation	Waste may be transported by truck, barge and/or train to disposal or re-processing sites. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would need to be tracked.	Related
B8 Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
B9 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
B10 Electricity Usage	Electricity may be required for operating the baseline facility. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
Onsite SS's during Baseline Operation		

B5 Waste Disposal	Waste may be handled at a disposal site by transferring the material from the transportation container, spreading, burying, processing, otherwise handling the waste using a combination of loaders, conveyors and other mechanized devices. This equipment would be fuelled by diesel, gasoline or natural gas, resulting in GHG emissions. Other fuels may also be used in some rare cases. Quantities and types for each of the energy inputs may need to be tracked.	Controlled
B6 Waste Decomposition	Waste may decompose in the disposal facility (typically a landfill site) resulting in the production of methane. A methane collection and destruction system may be in place at the disposal site. If such a system is active in the area of the landfill where this material is being disposed, then this methane collection must be accounted for in a reasonable manner. Disposal site characteristics and mass disposed of at each site may need to be tracked as well as the characteristics of the methane collection and destruction system.	Controlled
B7 Methane Generation Potential	Waste decomposes to produce methane. The amount of waste that has not yet decomposed has the potential to produce methane at a future period of time. This methane generation potential would be tracked.	Controlled
Downstream SS's during Baseline Operation		
	None	
Other		
B11 Development of Site	The site of the waste processing and disposal facilities may need to be developed. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
B12 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
B13 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
B14 Construction on Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity.	Related

B15 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
B16 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline condition were compared and evaluated as to their relevancy using the guidance provided in Annex VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion or conditions upon which SS's may be excluded is provided in **TABLE 2.3** below. All other SS's listed previously are included.

TABLE 2.3: Comparison of SS's

1. Identified SS	2. Baseline (C, R, A)	3. Project (C, R, A)	4. Include or Exclude from Quantification	5. Justification for Exclusion
Upstream SS's				
P1 Waste Generation	N/A	Related	Exclude	Excluded as the generation of waste is not impacted by the implementation of the project are likely functionally equivalent in both scenarios.
B1 Waste Generation	Related	N/A	Exclude	
P2 Collection and Transportation	N/A	Related	Exclude	Excluded as the emissions from transportation are likely functionally equivalent in both scenarios.
B2 Collection and Transportation	Related	N/A	Exclude	
P3 Waste Processing	N/A	Related	Exclude	Excluded as the emissions from waste processing are a component of an integrated waste management plan and would therefore be functionally equivalent both scenarios.
B3 Waste Processing	Related	N/A	Exclude	
P4 Waste Transportation	N/A	Related	Exclude	Excluded as the emissions from transportation are likely functionally equivalent in both scenarios.
B4 Waste Transportation	Related	N/A	Exclude	
P9 Fuel Extraction / Processing	N/A	Related	Include	N/A. Limited to fuel use under P6 Landfill System Operation.
B8 Fuel Extraction / Processing	Related	N/A	Exclude	Excluded as these SS's are not material as the emissions in other baseline SS's are excluded.
P10 Fuel Delivery	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under proposed greenhouse gas regulations.
B9 Fuel Delivery	Related	N/A	Exclude	
P11 Electricity Usage	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under proposed greenhouse gas regulations.
B10 Electricity Usage	Related	N/A	Exclude	
Onsite SS's				
P5 Waste Disposal	N/A	Controlled	Exclude	Excluded as the disposal of waste is not impacted by the implementation of the project and are likely functionally equivalent in both scenarios.
B5 Waste Disposal	Controlled	N/A	Exclude	
P6 Aerobic Landfill Bioreactor Operation	N/A	Controlled	Include	N/A

B6 Waste Decomposition	Controlled	N/A	Include	N/A
P7 Venting	N/A	Controlled	Include	N/A
P8 Fugitive Emissions	N/A	Controlled	Include	N/A
B7 Methane Generation Potential	Controlled	N/A	Include	N/A
P18 Methane Generation Potential	N/A	Controlled	Include	N/A
Downstream SS's				
None				
Other				
P12 Development of Site	N/A	Related	Exclude	Emissions from site development are not material given the long project life, and the minimal site development typically required.
B11 Development of Site	Related	N/A	Exclude	Emissions from site development are not material for the baseline condition given the minimal site development typically required.
P13 Building Equipment	N/A	Related	Exclude	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
B12 Building Equipment	Related	N/A	Exclude	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
P14 Transportation of Equipment	N/A	Related	Exclude	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
B13 Transportation of Equipment	Related	N/A	Exclude	Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required.
P15 Construction on Site	N/A	Related	Exclude	Emissions from construction on site are not material given the long project life, and the minimal construction on site typically required.
B14 Construction on Site	Related	N/A	Exclude	Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required.
P16 Testing of Equipment	N/A	Related	Exclude	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
B15 Testing of Equipment	Related	N/A	Exclude	Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required.
P17 Site Decommissioning	N/A	Related	Exclude	Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required.
B16 Site Decommissioning	Related	N/A	Exclude	Emissions from decommissioning are not material for the baseline condition given the minimal decommissioning typically required.

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.4**, below and for the SS's under the flexibility mechanisms in **APPENDIX A**. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\text{Emission Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Methane}}$$

$$\begin{aligned}\text{Emissions}_{\text{Project}} = {} & \text{Emissions}_{\text{Landfill Bioreactor Operation}} + \text{Emissions}_{\text{Venting}} \\ & + \text{Emissions}_{\text{Fugitive}} + \text{Emissions}_{\text{Fuel Extraction / Processing}} \\ & + \text{Emissions}_{\text{Methane Generation Potential}}\end{aligned}$$

Where:

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition.

$\text{Emissions}_{\text{Methane}}$ = emissions under SS B6 Waste Decomposition and SS B7 Methane Generation Potential

$\text{Emissions}_{\text{Project}}$ = emissions under the project condition.

$\text{Emissions}_{\text{Aerobic Landfill Bioreactor Operation}}$ = emissions under SS P6 Aerobic Landfill Bioreactor Operation

$\text{Emissions}_{\text{Venting}}$ = emissions under SS P7 Venting

$\text{Emissions}_{\text{Fugitive}}$ = emissions under SS P8 Fugitive Emissions

$\text{Emissions}_{\text{Fuel Extraction / Processing}}$ = emissions under SS P9 Fuel Extraction and Processing

$\text{Emissions}_{\text{Methane Generation Potential}}$ = emissions under SS P18 Methane Generation Potential

TABLE 2.4: Quantification Procedures

1. Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P6 Aerobic Landfill Bioreactor Operation	$Emissions_{Aerobic\ Landfill\ Bioreactor\ Operation} = \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2}); \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4}) ; \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N20})$					
	$Emissions_{Aerobic\ Landfill\ Bioreactor\ Operation}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's.
	Volume of Each Type of Fuel / Vol. $Fuel_i$	L, m^3 or other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Each Type of Fuel / EF $Fuel_{i\ CO2}$	Kg CO_2 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF $Fuel_{i\ CH4}$	kg CH_4 per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF $Fuel_{i\ N2O}$	kg N_2O per L, m^3 or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P7 Venting	$Emissions_{Venting} = [CH_4] * Q * t$					
	$Emissions_{Venting}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated.
	Concentration of methane exiting the vents / $[CH_4]$	kg / m^3	Measured	Direct metering of concentration of methane in a statistically relevant number of monitoring wells.	Continuous	Direct measurement is standard practice and highest level possible. The monitoring wells may be tied together such that the flow is aggregated and a single measurement point is established, or it may be averaged across multiple measurement points.

	Flow rate of air being blown into the system / Q	m^3 / day	Measured	Direct metering of gross airflow injected into the landfill cell(s).	Continuous	Direct measurement is standard practice and highest level possible.
	Time of system operation / t	Days	Measured	Direct metering.	Continuous	Direct measurement is standard practice and highest level possible.
P8 Fugitive Emissions	$\text{Emissions}_{\text{Fugitive}} = [CH_4] * Q * A * t$					
	$\text{Emissions}_{\text{Fugitive}}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated.
	Concentration of methane escaping from the landfill / $[CH_4]$	kg / m^2	Measured	Direct metering of concentration of methane in a statistically relevant flux chamber sampling locations.	Quarterly	Direct measurement is standard practice and highest level possible.
	Flow rate of methane escaping from the landfill to the chamber / Q	m^3 / m^2 / hr	Measured	Direct measurement of the time it takes for the volume of the flux chamber to fill measured as the time a given	Quarterly	Direct measurement is standard practice and highest level possible.
	Surface area of the landfill / A	m^2	Estimated	Area of landfill surface measured from aerial photos or other maps, in consideration of topography.	Annual	Most reasonable means of assessing area.
	Time in a Quarter / t	Hr	Measured	Set as 91.25 hours	Annual	Constant
P9 Fuel Extraction and Processing	$\text{Emissions}_{\text{Fuel Extraction / Processing}} = \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,CO2})$; $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,CH4})$; $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,N2O})$					
	$\text{Emissions}_{\text{Fuel Extraction / Processing}}$	kg of CO2e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on-site is likely aggregated for each of these SS's.

	Volume of Each Type of Fuel Combusted for P6 / Vol. Fuel $_i$	L/ m^3/ other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Each Type of Fuel Fuel Including Production and Processing / EF Fuel $_{i\ CO2}$	kg CO_2 per L/ m^3/ other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel Including Production and Processing / EF Fuel $_{i\ CH4}$	kg CH_4 per L/ m^3/ other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel Including Production and Processing / EF Fuel $_{i\ N2O}$	kg N_2O per L/ m^3/ other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P18 Methane Generation Potential	Emissions $_{Methane\ Generation\ Potential} = L_o * m$					
	Emissions $_{Methane\ Generation\ Potential}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated.
	The potential for methane generation of the landfill remaining at the end of the project period / L_o	kg of CH_4 / tonne of waste	Measured	Direct measurement using a Biochemical Methane Potential Assay, with a statistically relevant number of samples taken from across the landfill cell(s).	Annual	Direct measurement is standard practice and highest level possible.

	Mass of the landfill at the start of the project / m	tonnes of waste	Measured	Estimated from direct measurement of waste received at the landfill.	Annual	Direct measurement is standard practice and highest level possible.
Baseline SS's						
B6 Waste Decomposition and Methane Collection / Destruction and B7 Methane Generation Potential	$\text{Emissions}_{\text{Methane}} = L_o * m$					
	$\text{Emissions}_{\text{Methane}}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated.
	The potential for methane generation of the landfill at the start of the project period / L_o	kg of CH_4 / tonne of waste	Measured	Direct measurement using a Biochemical Methane Potential Assay, with a statistically relevant number of samples taken from across the landfill cell(s).	Annual	Direct measurement is standard practice and highest level possible.
	Mass of the landfill at the start of the project / m	tonnes of waste	Measured	Estimated from direct measurement of waste received at the landfill.	Annual	Direct measurement is standard practice and highest level possible.

2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in **TABLE 2.5**, below.

2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be to conduct for the project.

2.6.1 Record Keeping

Record keeping practises should include:

a. Electronic recording of values of logged primary parameters for each measurement interval;
b. Printing of monthly back-up hard copies of all logged data;
c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
d. Retention of copies of logs and all logged data for a period of 7 years; and
e. Keeping all records available for review by a verification body.

2.6.2 Quality Assurance/Quality Control (QA/QC)

QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

a Protecting monitoring equipment (sealed meters and data loggers);
b Protecting records of monitored data (hard copy and electronic storage);
c Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
d Comparing current estimates with previous estimates as a 'reality check';
e Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
f Establish minimum experience and requirements for operators in charge of project and monitoring; and
g Performing recalculations to make sure no mathematical errors have been made.

TABLE 2.5: Contingent Data Collection Procedures

1.0 Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P6 Aerobic Landfill Bioreactor Operation	Volume of Each Type of Fuel / Vol. Fuel $_i$	L, m^3 or other	Estimated	Reconciliation of volume of fuel purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P7 Venting	Concentration of methane exiting the vents / [CH_4]	kg / m^3	Estimated	Linear average of the average concentration for the on the five days prior and post gap in continuous data set.	Daily	Given that the bioreactor systems are actively managed to for consistent operation, the averaging of these average concentrations will provide a reasonable estimate.
	Flow rate of air being blown into the system / Q	m^3 / day	Estimated	Weighted average of the average daily flow rate on the five days prior and post gap in continuous data set.	Daily	Given that the bioreactor systems are actively managed to for consistent operation, the averaging of these flow rates will provide a reasonable estimate.
	Time of system operation / t	days	Estimated	Estimated based on operational data (fuel use, electricity consumption, operator notes).	Daily	For days when the system is shown to be in any part operational, the system is considered to be operational for the whole day as this is conservative.
P8 Fugitive Emissions	Concentration of methane escaping from the landfill / [CH_4]	kg / m^2	Estimated	Estimated as the average of the value from the previous and following quarterly monitoring.	Quarterly	Given that the bioreactor systems are actively managed to for consistent operation, the averaging of these concentrations will provide a reasonable estimate.
	Flow rate of methane escaping from the landfill to the chamber / Q	m^3 / m^2 / hr	Estimated	Estimated as the average of the value from the previous and following quarterly monitoring.	Quarterly	Given that the bioreactor systems are actively managed to for consistent operation, the averaging of these flow rates will provide a reasonable estimate.
P9 Fuel Extraction and Processing	Volume of Each Type of Fuel / Vol. Fuel $_i$	L, m^3 or other	Estimated	Reconciliation of volume of fuel purchased within given	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

1.0 Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
				time period.		
P18 Methane Generation Potential	The potential for methane generation of the landfill at the start of the project period / L_o	kg	None			
Baseline SS's						
B6 Waste Decomposition	The potential for methane generation of the landfill at the start of the project period / L_o	kg	None			